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Research Paper

Personal Thermal Comfort through Psychological Adaptation: The Effects of Cognitive Flexibility and Resilience †

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Abstract
Due to the climate change impact, personal thermal comfort (PTC) studies in buildings have been highlighted to reconsider previous results. PTC causes thermal adaptation) physical, physiological, and psychological adaptation (that is the process of acclimatization to different conditions. Thermal comfort is affected by environmental, personal, mental, cognitive, and behavioral criteria. This study was conducted to emphasize the effects of psychological components on PTC in order to improve offices indoor environment quality and reduce energy consumption. In this perspective, cognitive flexibility and resilience have been selected to examine PTC and the ability to accept and choose thermal adaptive strategies based on cognitive characteristics. The research question is: do different cognitive flexibility and resilience level lead to different levels of PTC and conscious/unconscious reaction? To answer this question and calculate comfort temperature, field study was carried out in an office building. The study had two steps: questionnaire and on-site measurements. The questionnaire included an assessment of psychological components, personal components, and thermal responses scales. Environmental components were measured using mobile instruments and the nearest weather station data. A study of 108 participants indicated that cognitive flexibility and resilience had a significant correlation with thermal sensation, thermal comfort, and thermal preferences. So, we can have linear and logistic regression models to predict adaptive behavior, thermal comfort, and thermal preferences based on psychological and personal components. Analysis of comfort temperature using the Griffiths method showed indoor temperature should be 23.7°C for the majority of occupants. We can also be sure that at least two degrees change in indoor temperature is needed to shift occupants' thermal sensation.

Keywords: *Thermal adaptation, Thermal comfort, Cognitive flexibility, Resilience, Office buildings.*

1. INTRODUCTION

Sick Building Syndrome (SBS) has received a great deal of attention in the period of 1970s to 1990s which caused increased attention toward the interior quality issue (Antoniadou & Papadopoulos, 2017). One aspect of interior quality is considering the personal thermal comfort that has been mentioned in the EN15251 standard (Albatayneh et al., 2018). In an environment with appropriate quality, personal mental wellness is satisfied considering environmental, mental, and emotional factors (Johnson et al., 2018). An appropriate level of thermal comfort is achieved with different methods

†The article is based on a PhD thesis "Thermal comfort in office building considering psychological factor" by the first author, under the supervision of the second and third authors.

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in different environments. It is not possible to generalize a single method for all cases (Frontczak & Wargocki, 2011). It means we may see users with different reactions in the same situation.

Although many studies have been conducted in different situations, users' behavior is very complex and requires interdisciplinary studies for full comprehension. On the one hand, behavior is influenced by external factors such as culture, economics, and climate on the one hand, and by internal factors such as individual comfort preferences, physiological, and psychological issues on the other hand (Djamila, 2017; Hong & Yan, 2018).

Identifying the relationships between the various components and the extent of their impact on thermal comfort lead to the presentation of conceptual and sometimes quantitative models that are effective in the design process and post-occupancy maintenance. Model prediction can be based on univariate or multivariate relationships between the studied components (Gunay et al., 2013).With a review of these models as well as models in the field of psychology, the scarcity of psychological studies in thermal comfort studies became more pronounced. Therefore, new research should incorporate mixed-methods research and interdisciplinary approaches from different fields of knowledge to address the mutual connection of these two fields: thermal comfort and related psychological aspects. Because what one perceives (socio-physical-environmental components, comfort, and the level of control over the environment), beliefs (personal components), and what he has done so far (previous behaviors) can influence his future behavior too.

When a person spends a long time in a space, thermal adaptation may not be solely influenced by temperature conditions.This article is part of a larger study that measures the effects of 60 different components (in 5 groups: environmental, personal, physical, physiological, psychological) on personal thermal perception. To focus on personal differences in thermal comfort models and calculate efficient comfort temperature, this study examines the personal thermal perception (based on thermal scales) and the ability to accept a situation or choose thermal adaptive strategies based on the personal cognitive characteristics (or psychological components).

Since thermal adaptation focuses on the ability of the individual to adapt to existing conditions, this study has attempted to identify components with similar concepts related to adaptability in psychology. From this perspective, after reviewing more than 50 criteria, cognitive flexibility and resilience have been selected. On the other hand, as one's thermal perception leads to a conscious and unconscious reaction, this aspect has also been investigated. It is hypothesized that if a person has cognitive flexibility and high resilience, he/she will be more adapted to the environmental conditions and will have a higher level of thermal comfort and thermal satisfaction (Figure 1). People with such traits are either less likely to be dissatisfied or find a solution to address inappropriate environmental conditions and achieve comfort. This assumption raises two basic questions: 1) Does cognitive flexibility and resilience lead to positive or negative changes in personal thermal comfort? 2) Does any of the above components affect one's conscious and unconscious reactions? In order to answer these questions, a field study in a Shiraz university main administration building was conducted. The field study was chosen to encounter a real situation (right here, right now) because it is more helpful for future building design to consider exact reactions in real life. Shiraz University main administration building can be a good example for field study as it has two different parts with different construction methods that help us to compare results. Due to the multiplicity of studied criteria and emphasis on personal thermal comfort, this paper focuses on only one building to find out the most important criteria. So, this study can be the basis for future researches in other buildings with fewer and more focused criteria.

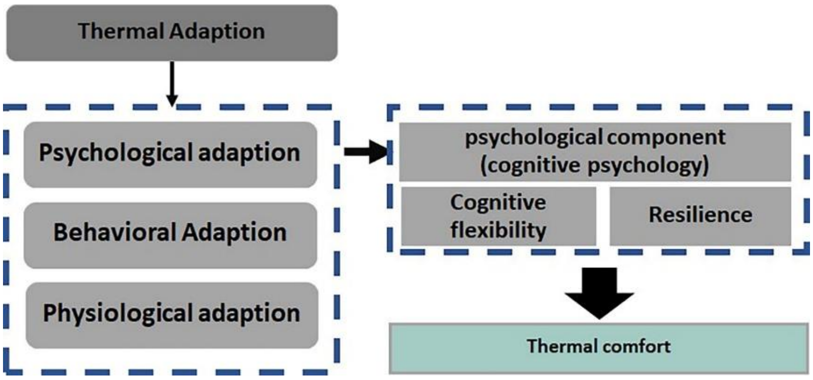

Fig 1. The Hypothesis of the Relationship between Psychological Components and Thermal Adaptation

2. LITERATURE REVIEW

2.1. Thermal Comfort Background

The word "comfort" encompasses different aspects, but thermal comfort is among its most important ones. Gagge et al. (1967) describe thermal comfort as a state of an individual's feeling that has two endpoint in a spectrum; feeling of pleasurable and adaptable conditions to health and happiness on the one hand, dissatisfaction, pain, and unpleasant conditions and on the other hand (Marcel Schweiker et al., 2017). Sensitivity to thermal conditions is known as thermal sensation and is a major factor in thermal comfort studies (Givoni et al., 2003).

Thermal comfort studies are presented in two different domains simultaneously, each with its own capabilities and limitations: the Logical or Heat Balance Model (HBM) and Thermal Adaptation Model (TAM). The HBM extracts the required data using the climate chamber method, which can be found in Fanger's research. The TAM focuses on actual conditions (field study) to collect relevant data (Djongyang et al., 2010). Many studies show the effect of environmental components on thermal comfort. This view can explain only 50% of the results in field studies. This difference cannot be accurately described by the environmental components. It seems that psychological adjustment plays a significant role in accepting physical environment and tolerating it (Auliciems, 1981; Nikolopoulou & Steemers, 2003). In addition to environmental components (temperature and humidity), other criteria such as contextual factors (structural characteristics, orientation, type of heating and ventilation system, season, pattern of residence, and time), physiological factors (age, gender, clothing type, activity type, food, and drink), and psychological factors (expectations, habits, perception, economic and environmental concerns, and lifestyle) affect thermal comfort (Korsavi & Montazami, 2018).

Attention to individual differences in the perception of thermal comfort is considerable in recent studies (Frontczak & Wargocki, 2011; Law, 2013; Lin et al., 2016; Lodge & Park, 2016; Marcel Schweiker et al., 2018; Townley et al., 2011; Wang et al., 2018). Recent research has sought to identify other contributing factors rather than focusing solely on the environment as the key factor in providing thermal comfort (in accordance with the HBM) and try to make a numerical expression of a qualitative variable et al., 2009).

As a psychological expe (Aljawabra & Nikolopoulou, 2010; Brien & Gunay, 2014; Cohen et al., 2013; De Dear et al., 2013; Foo & Mavrogianni, 2018; Indraganti & Rao, 2010; Jowkar & Montazami, 2018; Knez & Thorsson, 2006; Maras et al., 2013; Rupp et al., 2018; Wang et al., 2018; Yaorience, thermal sensation depends on one's sense and perception of the environment (Knez & Thorsson, 2006; Marino et al., 2011; Parsons, 2002). This is also influenced by personal experiences and expectations (Cole & Loarch, 2003; Richard De Dear et al., 1998; Höppe, 2002). Lifestyle and beliefs as a conscience of personal experiences and expectations help anyone to survive in diverse conditions (Nicol & Humphreys, 2002; Fergus Nicol & Roaf, 2017). This durability is described in terms of adaptability or thermal adaptation. The ability to adapt is expressed in three ways: behavioral adaptation, psychological adaptation, and physiological adaptation. Analyzing the thermal adaption process of occupants leads many studies to measure different variables in the real-time situation (right here-right now) without any limitation for participants. In this way, the result shows the real lifestyle in contrast to climate chamber studies. The main focus of this research is on psychological adaptation, which is not yet fully understood in thermal comfort researches. Consequently, it is important to understand the relationships between psychological components to determine how they play a role in design considerations and whether these components influence the design process or vice versa.

2.2. Psychological Components

Different models have been presented so far, focusing on different aspects of thermal adaptation such as factors influences thermal adaptation behaviors (Korsavi, 2018; Nikolopoulou & Steemers, 2003), psycho-physiological components (Auliciems, 1981), social and economic components (Shooshtarian& Ridley, 2017), investigating behavioral aspects (Chen & Ng, 2012), and personal comfort models (Brien & Gunay, 2014). Studies conducted in annex 66 and annex 79 are of holistic research in different countries, that can upgrade current standards (Hong et al., 2017; Wagner & Brien, 2018; Dan Yan & Hong, 2018).

Based on these kinds of studies, it can be concluded that there are different theories about the behavior and attitude of people regarding building physics. Some of these include Bandura's (1986) Social-Cognitive Theory (SCT), Ajzen's (1991) Theory of Planned Behavior (PB), Latour's (1994) Theory of Actor Networks (AN), Stern's (2000) Attitude-Behavior-Context Model (ABC), Shove's (2014) Theory of Practice (Abrahamse & Steg 2009).

Meanwhile, the Social-Cognitive Theory describes human behavior as a dynamic interaction between environmental, individual, and behavioral components. By applying SCT, it will be seen that how users interact with the social and physical components of the environment, including building characteristics, social norms in a dynamic work environment, perception of comfort, and control of the environment in shared spaces, are interconnected with their behavior (D'Oca et al., 2017).

Personal psychological characteristics are effective in both perceiving and modifying the environment (Nikolopoulou & Steemers, 2003). People can expect a wide variety of mental and psychological conditions that lead to a wide range of thermal sensations and different sense of satisfaction. As a result, occupants can accept responsibility for behavioral adaptation and control of conditions (H.B. Rijal et al., 2018).Some of these psychological criteria are inherent characteristics of space, while others are highly personal and brought to the environment by individuals (Nikolopoulou & Steemers, 2003). So, it is necessary to revise the thermal comfort indices by conducting large-scale field studies with a significant number of participants to understand the effect of psychological factors on personal thermal comfort (De Dear et al., 2013; H.B. Rijal et al., 2018).

If these criteria and their effect are determined, the model can be formulated and serve as a basis for predicting future personal behaviors and even mechanical reactions. Cognitive function describes a process that requires conscious mental effort for reaction (Taylor et al., 2016). The important thing about the cognitive process is people can find a solution for psychological problems in their cognitive ability. Therefore, if the cognitive ability can affect adaptive behaviors, it is necessary to examine its relationship with the theory of thermal adaptation. On the other hand, different environmental conditions can have a negative effect on a person's cognitive function. Various studies show that heat (Hocking et al., 2001; Bandelow et al., 2010; Morley et al., 2012; Parker et al., 2013), cold (Marrao et al., 2005; Mäkinen et al., 2006; Adam et al., 2008a; Spitznagel et al., 2009; Muller et al., 2012; Taylor et al., 2014), lack of oxygen (Papadeli et al., 2008; de Aquino Lemos et al., 2012; Muller et al., 2012; Ando et al., 2013; Neuhaus & Hinkelbein, 2014) have affected the human cognitive process (Taylor et al., 2016).

As is shown, the relationship between environmental conditions and their effect on the cognitive process have been mentioned in many studies. But the inverse relationship, that is, the effect of the cognitive ability on the perception of environmental conditions and thermal adaption, needs to be measured.

It is clear that users' attitudes and behaviors originate from a variety of structured features that are difficult to measure simultaneously. Among the psychological components, some characteristics are in the form of temporary and short-term emotions and their effect on thermal perception is considered temporary. Therefore, the components that have a deeper impact on behavior and thoughts and cause a reaction should be considered. In an exploratory study, it was determined that cognitive flexibility and resilience (as psychological components) can be evaluated according to similar basic principles to thermal adaptation theory.

Cognitive flexibility is an individual characteristic of a person's willingness to accept a change that is commensurate with his or her level of intelligence and cognitive ability. Cognitive flexibility is dependent on a larger set of cognitive abilities called executive functions that are very helpful in problem-solving, pursuit of goals, and achievement (Bernardo & Presbitero, 2018). In addition, the ability to modify cognitive sets and attitudes to respond to changing goals, thoughts, behavior is derived from this property. It also includes a range of cognitive functions such as attention, perception, and needs monitoring (Dennis & Vander, 2010; Ionescu, 2012; Johnco et al., 2014; Shareh et al., 2014). Against the attitude of cognitive flexibility is cognitive inertia, an unchanging frame of mind that insists on maintaining point of view and behavior. Over-reliance on existing mental models makes any change in the options ahead unacceptable to the person, even if there is a change in their needs or environment. The role of cognitive flexibility leads to innovative ways of dealing with the issue that provides the conditions for adapting to new needs and transferring from the usual, simple, and already experienced solutions to the new solutions. This approach can be termed adaptive thinking that expresses high-level cognitive abilities (Bernardo & Presbitero, 2018; Ionescu, 2012).

Another psychological component is resilience that is a process of positive adaptation to adverse life circumstances (Lim et al., 2019). The concept of resilience encompasses two aspects: the process of coping with adversity and recovering from trauma by using environmental resources (Ertekin Pinar et al., 2018; Li et al., 2019; Sánchez & Lopez-Zafra, 2019; Shi et al., 2019; Valdes et al., 2019; Xiao et al., 2019). Resilience can be considered as an outcome and even as a personal capacity (van der Meulen et al., 2019). The main objective of resilience is to keep individuals in a stable situation to lead to reasonable physical functions and reactions (Mętel et al., 2019).

3. MATERIALS AND METHODS

A central idea in energy-related studies in buildings is that real events do not take place in laboratory environments, but rather in everyday living environments where one's natural habits are very important. Numerous methods for observing one's behavior have been introduced and used so far (Cheung & Jim, 2017; Taleghani et al., 2013; Wang et al., 2018). Among them, the interview and questionnaire methods, by relying on one's self-report, will be helpful in gathering individual insights, habits, and beliefs (Gunay et al., 2013; Lau et al., 2018). The process is to collect environmental data and record simultaneous individual's thermal responses in real-time while researcher intervention is minimized (Nicol & Humphreys, 2002). To achieve the research objective, an integrated method was developed. Field study including a questionnaire and on-site measurement was carried out in the Shiraz University main office building (29.59° N, 52.58° E) for 4 days in winter, 2019. Personal, environmental, and psychological components are independent variables and thermal responses are dependent variables. Figure 3 shows the measured variables.

3.1. Tools and Instruments

Since this article is part of a larger study, only some of the measured components based on the paper's purpose are introduced. The main study consists of two parts: the questionnaire and observation. Although a large number of questions may increase the assessment duration, it is possible to understand the cumulative effect of components. The order of questions was chosen in a way to gather information about thermal perception at first and then other collected data. Because thermal studies in the real situations should not take more than 10 minutes although there was enough time for answering the psychological questionnaires. The written questionnaire consists of three parts:

I) Information about personal components (age, sex, height, and weight), thermal responses (thermal sensation vote, thermal comfort, thermal pleasure, temperature preferences, humidity preferences, air velocity preferences, radiation preferences thermal acceptance, and overall comfort), conscious adaptation (ten different adaptive behavior), unconscious adaptation (heat/cold sensation in especial part of the body) were collected in the first part of the study.Personal components and conscious/unconscious adaptation behaviors question were designed in the form of yes/no questions. The validity and reliability of the questions have been investigated regarding previous articles and studies (Barthelmes et al., 2018; Chung & Lau, 2018; Földváry et al., 2018; Foo & Mavrogianni, 2018; Montazami et al., 2017; Schweiker et al., 2019; Schweiker et al., 2017; Shooshtarian & Rajagopalan, 2017; Wagner & Brien, 2018; Wagner & O'Brien, 2018; Yan & Hong, 2018). Cronbach's alpha of the questionnaire was measured to confirm the reliability coefficient. Its value was 0.7 that is acceptable. Reliable standards (ASHRAE 55-2017 and European EN15251 standards) recommend different scales (Humphreys & Hancock, 2007; Kim et al., 2018; Schweiker et al., 2017) for expressing comfort conditions as shown in Figure 2. So thermal responses are measured based on these scales.

II) There are several methods for measuring cognitive flexibility, including the use of executive functions, such as the Wisconsin Card Sorting Test, Stroop Color and Word Test, OTest, and Trail-making Test. Self-reported assessment tools are also used in this area. These two methods measure cognitive flexibility with different structures. Methods based on executive functions focus on only one cognitive behavior, while self-reported tools such as the Behavior Rating Inventory of Executive Functions, Alternate Uses Test, and Cognitive Flexibility Scales are designed to evaluate decision-making in real-world multidimensional situations (Bernardo & Presbitero, 2018). Various factors are important in choosing the type of questionnaire. Limitations such as time and cost, increasing the effect of test repetition, and the need for manpower to perform the test in the first category of the test mentioned above are very problematic, which may also make the test unusable. So, the Cognitive Flexibility Inventory (CFI) was selected due to its sufficient validity and speed in data collection.

The CFI was developed by Dennis and Vander to measure one's flexibility in an effective interactive context. The questionnaire consists of 20 items with three subscales of controllability in difficult situations, perceptions of multiple alternatives, and the ability of behavior justification (Dennis & Vander, 2010; Johnco et al., 2014). Three aspects of cognitive flexibility seek to measure three levels: a) individual's desire to perceive a controllable situation ($CFI_{controllability}$), b) the ability to find appropriate alternatives for events ($CFI_{multiple\ Answer}$), and c) the ability to find/create solutions for difficult situations ($CFI_{Behavior}$). In this way, the progress of the individual in creating flexible thinking can be reviewed. The reliability coefficient of the CFI questionnaire is 80 percent.

III) Resilience was measured using Connor and Davidson Resilience Measurement Scale (CD-RISC). The CD-RISC was developed by Connor and Davidson in 25 items. While early studies in the field of psychology had acceptable validity and reliability, this scale considers experiences such as changes, personal problems, illness, stress, failure, and pain (Cai et al., 2017; Connor & Davidson, 2003; Ertekin Pinar et al., 2018; Mętel et al., 2019).

Participant ability in cognitive flexibility and resilience was evaluated using a 5-points Likert scale.

Observation and on-site measurement managed by 4 tools to record blood pressure, heart rate, body temperature as personal components, and indoor air temperature and relative humidity as environmental components. Suitable devices for measuring environmental conditions were selected based on ISO-7726 standard and ASHRAE handbook of fundamentals (ASHRAE, 2017; Shooshtarian et al., 2016). Figure 3 shows instruments and their accuracy. The recommended height for installing the temperature and humidity data logger is between 0.6 and 1.1, which indicates the body center of gravity. The data logger was installed at a height of 1 meter in this study. The accuracy and required range of measurement are in accordance with ISO-7726. To ensure the calibration of the main device, the peripheral device was also used to record environmental data. Outdoor air temperature and relative humidity were recorded based on the nearest (and only) weather station in the Shiraz Airport (located at: 29.54° N, 52.58° E). Metabolic rate and clothing insulation were also recorded. But they were excluded from the analysis due to the lack of individual differences.

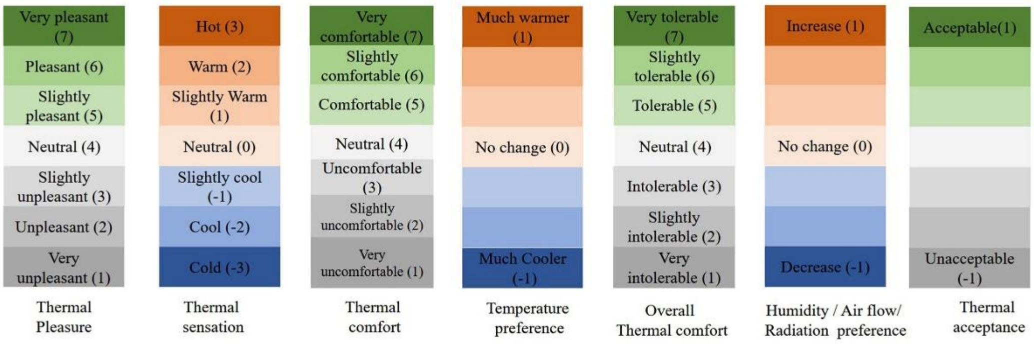

Fig 2. Thermal Response Scales

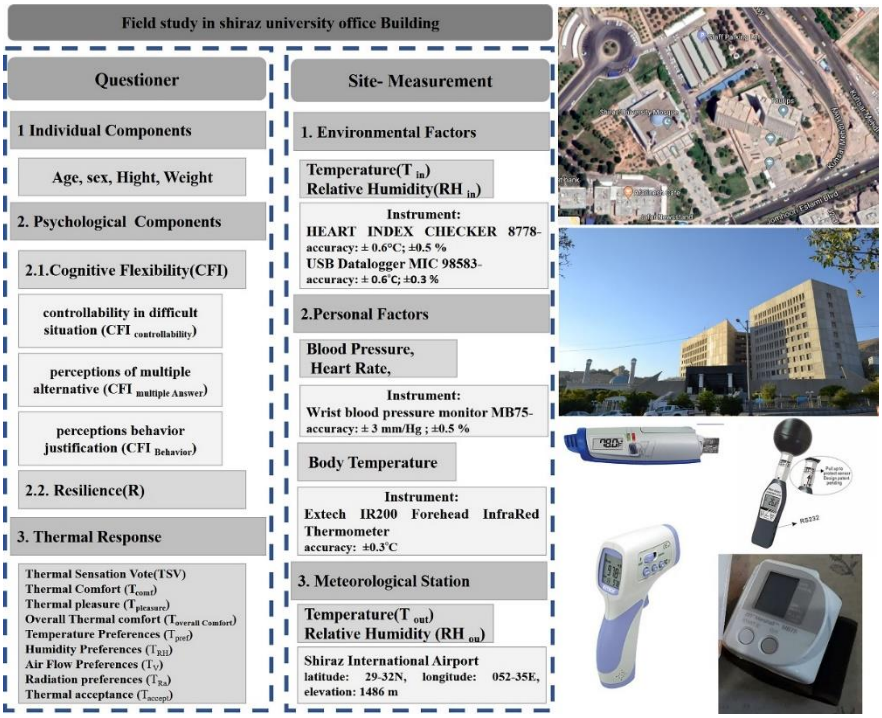

Fig 3. Variables and Tools Considered in the Field Study

3.2. Case Study Introduction: Building, Participants, and Procedure

The case study is the mixed-mode office building in the Shiraz University main administration building which is located on the northern side of Shiraz, Iran, (52.52°N, 29.63°E). According to the Koppen-Geiger climate classification, Shiraz is classified in the BSK group.According to research conducted in different years, the study area has a high-temperature level in Shiraz, which can affect the amount of energy consumption in buildings and macro-climate change. Therefore, it seems to be a good option for studying. Choosing 60 criteria (in a larger study) was because of the main goal to find out the most important components that affect personal thermal comfort. Hence, components' cumulative effect was studied in one building to be narrower down for future comparative studies. Shiraz University main administration building had some features that helped us achieve our goals.

The 138920 square meter building is oriented in the northwest and southeast direction in two blocks (with seven and ten stores). The building has concrete construction and an insulation layer in the walls. Central fan coil systems are used for heating and cooling. The heating system switches on at 5 AM in the morning and turns off at 3 PM (office hours: 8-16), but the occupants have control over the heating system to change the temperature or any other changes in the space. Two blocks in the building with different interior designs, structures, and mechanical systems provided the condition for comparing the results. Rooms with different orientation to the sun, multiple viewpoints, multi-story buildings, and permission to collect data were other reasons to choose this building. Accordingly, one building in one season study made enough data for the first step decision. Cognitive ability doesn't change too much during a one-year study in different seasons, hence the short-term study was chosen.

The field study was conducted in January 2019 for four days from 8 AM to 12 PM (Figure 4). In the adoption process, the test started at 8:30 AM. To prevent the effect of intervention factors such as fatigue in the afternoon, the measurement has been avoided. There was no compulsion to participate and oral and written consents were considered. There were no restrictions on participants to participate, so they can have freedom of their usual workday. The selection process of different parts of the building has been such that data collection is done when there were fewer clients, due to the reduced effect of interfering factors and problems in providing services. In total, there were 110 measurement subjects, and finally, by eliminating incomplete questionnaires, 108 were identified as useful in the analysis process. Some data converted to new components (e.g., age converted to age group, height, and weight into body mass index based on WHO standard (Maykot et al., 2018)) for better analysis. Each question in CFI and CD-RISC could have a 1-to-5 score, the total score was calculated by the sum of these scores. Thermal response scale coding is shown in Figure 2. The collected data were imported into SPSS software version 22 and statistical analyses including descriptive and inferential statistics (linear regression, logistic regression and multiple linear regression) were performed.

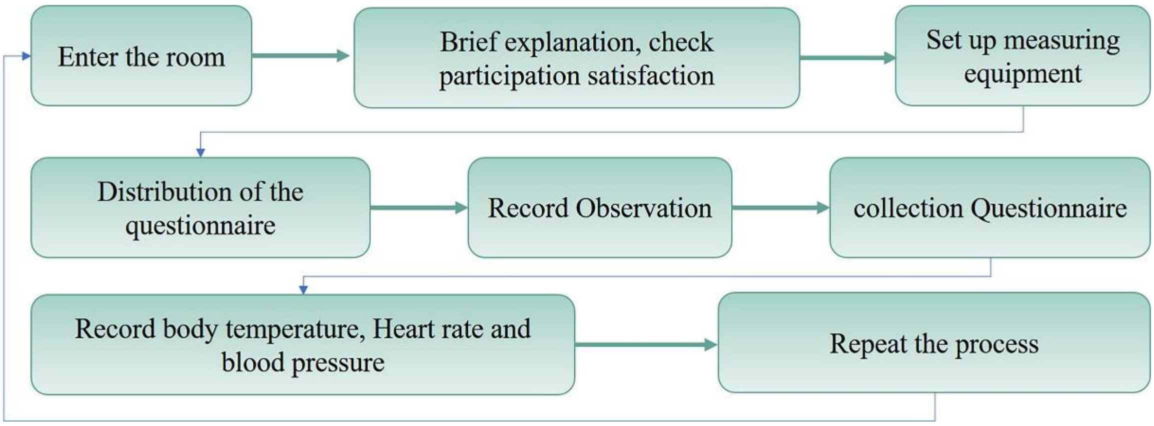

Fig 4. Data Collection and In-site Measurement Procedure

4. RESULTS

IParticipant of this study were 108 subjects including 41 females and 66 males (one person did not mention gender). The age group varies from 24 to 60 years. The majority of the age group is in the 31-45 years old range. The body weight was between 50 and 120 kg and the height between 1.55 to 1.86 meters. The average body temperature was 36$^{\circ C}$, the mean blood pressure was 126 mmHg with a minimum of 87 and a maximum of 183, and the heart rate was in the range of 49 to 98. The mean indoor air temperature was 23.67$^{\circ C}$, and the mean relative humidity was 24.86%. The mean outdoor air temperature in these four days was 14.52$^{\circ C}$ and the mean outdoor relative humidity was 40.82%.

IThen, the relationship of personal, environmental, and psychological components will be mentioned from two different points of view: a) the relationship between the cognitive flexibility and resilience, and b) the relationship between cognitive flexibility and resilience and environmental/personal components and thermal responses.

4.1. The Status of Participants' Psychological Components: Resilience and Cognitive Flexibility

As mentioned in Section 1.1, the authors need to know the status of the psychological components of participants to find the effect on their thermal responses. In Figure 5, the mean score of cognitive flexibility and resilience are presented. Since cognitive flexibility has three subscales ($\text{CFI}_{\text{controllability}}$, $\text{CFI}_{\text{multiple Answer}}$, $\text{CFI}_{\text{Behavior}}$), their mean is also declared. The mean score of resilience was 84.05 for females and 88.17 for males. In terms of cognitive flexibility, the mean total scores were 72.34 and 76.73 for females and males, respectively. The means in cognitive flexibility subscales were as follows: $\text{CFI}_{\text{controllability}}$ 27.73 and 28.80 in females and males; $\text{CFI}_{\text{multiple Answer}}$ 37.93 and 39.96 in females and males; and $\text{CFI}_{\text{Behavior}}$ 7.15 and 7.44 in females and males. As can be seen, in this study males are at a higher level of cognitive flexibility and resilience. Concerning cognitive flexibility, the difference between the two sex groups is much smaller.

With regard to age, resilience was the highest item in the age group of 46-60 years with a mean of 91.79, and the lowest in the age group of 31-45 years with an average of 85.84. Also, the age group of 46-60 had a higher average in cognitive flexibility (77.89). The age group of 31-45 years had the lowest average of cognitive flexibility (74.63).

4.2. Relationship between Personal and Psychological Components

Personal components have two parts: variables related to the participants' health characteristics and conscious/unconscious adaption reaction. As shown in Figure 6, no significant relationship was found between psychological and personal components such as age, body mass, and body temperature. In the case of gender, there is a weak correlation with the Eta coefficient correlation between sex as a categorical variable and psychological components as a continuous variable. The mean scores of resilience and cognitive flexibility were also significantly different between the two sex groups.

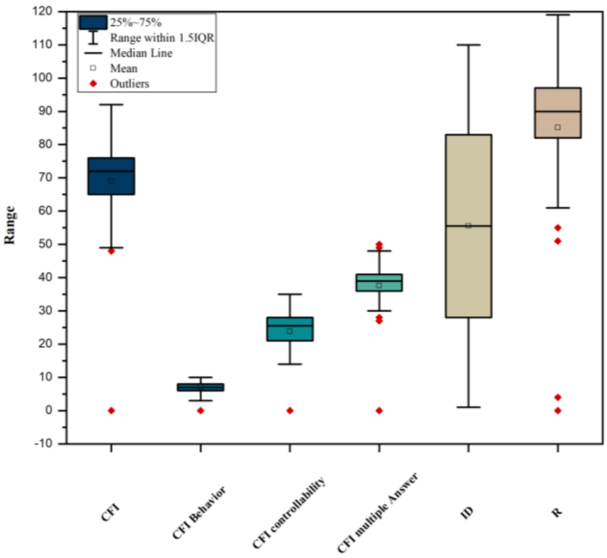

Fig 5. Psychological Component Scores

Adaptive behaviors are part of a person's conscious response to thermal dissatisfaction. Adaptive behaviors in this study include opening/closing windows, decreasing/increasing temperatures, cool/warm drinks, switching on/off the heating system, decreasing/increasing clothing, and changing the place. Figure 7 shows the percentage of participants choosing different adaptive behaviors. As shown, cool drinks and opening the window have a higher frequency, and this means participants need lower temperature and more fresh air.

AConsidering the research question (Do psychological components have any effect on choosing any conscious/ unconscious response?), in the first place, the correlation was considered between cognitive flexibility and resilience on one hand and conscious/unconscious reactions on the other hand. Figure 6 shows a moderate correlation between psychological components and adaptive behaviors in most cases. Among the subscales of cognitive flexibility subscales, CFI $_{Behavior}$ shows the weakest correlation with adaptive behaviors. So, it seems that choosing one adaptation behavior may depend on some level of psychological characteristics. To confirm this idea, the logistic regression model between psychological components and adaptive behaviors was used.

Because of having two binary options (yes/ no) to choose adaptive behaviors, the logistic regression method is used. Logistic regression helps determine the likelihood of belonging to a group, thus one can predict which adaptive behaviors were chosen based on the level of cognitive flexibility or resilience ability. In this case, the psychological components (resilience, cognitive flexibility, and its subscales) are considered as independent variables and adaptive behaviors are the dependent variables.

Omnibus tests of model coefficients and the Chi-square test show significant explanatory power and model efficiency. The goodness of fit, based on the Chi-square coefficient, was observed just for some of adaptive behaviors such as decreasing temperature, hot drink, displacement, and impossibility of change. It means that the prediction process is also significant. According to the Nagelkerke R-Square coefficient of determination, it is known what percentage of the variance of the adaptive behaviors (as a dependent variables) can be predicted based on psychological components (as an independent variables). This percentage is obtained between 12% and 15% for different behaviors is considered as an acceptable range.

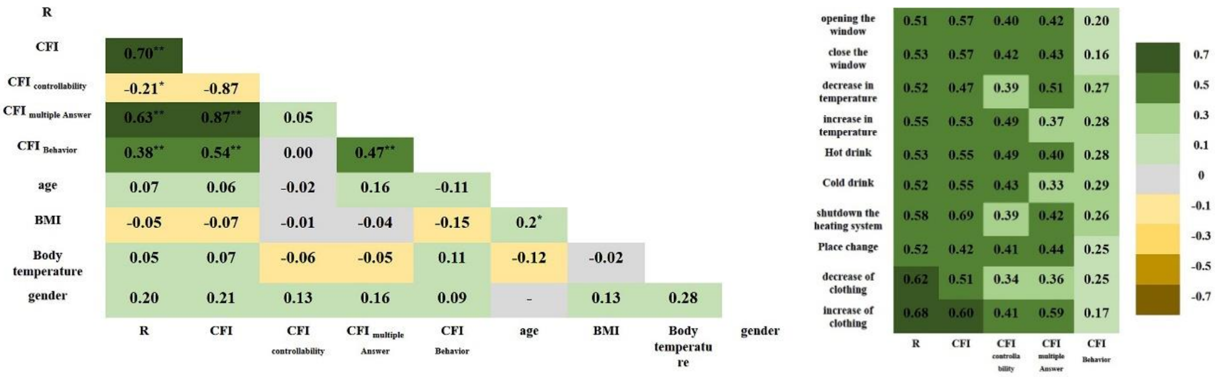

Fig 6. Correlation between Psychological and Personal Components

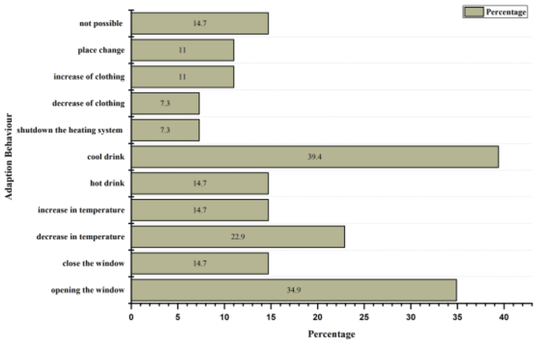

Fig 7. Percentage of Participants Choosing Different Adaptive Behavior

The significance of the Wald test in logistic regression shows which adaptive behaviors were able to predict based on the psychological components. As can be seen in Table 4, only the decreasing temperature can be predicted based on the resilience ability. The odds ratio (EXP) indicates the relationship between the dependent and independent variables. With an increase in resilience, the probability of choosing a decreasing temperature increases by a factor of 1.058. The logistic regression equation (Log-odd) for this variable is also presented in Table 1, with a constant coefficient of -6.216 and an independent variable coefficient of 0.057. If the minimum (52) and maximum (114) resilience scores (based on Figure 5) are incorporated in the log-odds and then calculated for each case of the logit equation, the probability would change. Therefore, it can be confidently stated that increasing one's level of resilience leads to an increased likelihood of choosing the adaptive behavior of decreasing the temperature.

An unconscious adaptive strategy of a person, as a physiological reaction, to upgrade a comfortable situation, is temperature change in the different parts of the body.These changes occur through the body's internal and surface sensors to maintain normal body temperature conditions. In the present study, the highest sensation of cold feeling was in the legs (by 34.9%) and then in the head (by 14.7%). Figure 8 shows Eta's correlation coefficient for expressing the relationship between point feelings (as nominal and binary variables) and psychological components (as scale variables). Regarding cognitive flexibility and resilience, there is a moderate or high correlation in most cases with a heat/cold sensation in different body parts based on the Eta coefficient.

In spite of the relatively high correlation between heat/cold point sensation and psychological components, in computing logistic regression between these two components, there is no significant logistic regression model to determine the probability of point sensation prediction based on psychological components. It means unconscious adaptation behaviors to achieve thermal comfort are not affected by psychological components.

4.3. Relationship between Environmental and Psychological Components

The relationship between environmental and psychological components has also been studied. Looking at Table 2, it is clear that only CFI $_{Behavior}$ had a significant relationship with the indoor air temperature and relative humidity. In this case, the linear regression model between this subscale and the indoor air temperature is also given in Table 3. The regression model for relative humidity has not been reported due to the insignificance of the coefficient. In expressing linear regression at this stage, it should be taken into account that cognitive flexibility and resilience are considered as dependent variables and climate components as independent variables. Based on the results in Table 2, if cognitive flexibility and resilience have effects on the thermal comfort model, it would be easy to predict them based on air temperature and relative humidity. This is important because air temperature and relative humidity can be measured easily. Indoor air temperature is recorded in most office environments by thermostats. Therefore, it is easy to predict CFI $_{Behavior}$ scores based on the indoor temperature. But designers should be careful about the generalization of the results because just in 4% (R Square= 0.040) of situations CFI $_{Behavior}$can be predicted based on indoor air temperature.

4.4. Influence of Psychological Components on Thermal Responses

As mentioned at the beginning of the paper, the main research question is investigating the relationship between psychological components and personal thermal responses. Thermal comfort perception is measured by different concepts such as thermal sensation vote (TSV), thermal pleasure ($T_{pleasure}$), thermal comfort (T_{comf}), thermal preference (T_{pref}), thermal acceptance (T_{accept}), and overall thermal comfort ($T_{overallcomf}$).

Figure 9 shows the average of participants' thermal responses.Given the frequencies of each option in thermal scales, one can see in which direction the thermal responses are headed. Participants' average TSV tends to be in a slightly warm level (between neutral and slightly warm). Based on the thermal comfort and considering the three end-of-scale options, 88% of people feel comfortable. This is in line with the ASHRAE 55 standard, which considers thermal comfort to be equivalent to 80% of people's satisfaction. Clearly, just 90.7% by thermal pleasure scale and 92.7% by overall thermal comfort scale belong to the comfort level. These percentages indicate the importance of examining the role of other factors in thermal comfort. On the other hand, 91.7% of people described the situation as acceptable. Neutral thermal conditions are defined as three intermediate options of the TSV scale (slightly cool, neither hot nor cold, and slightly warm). In this study, 93.3% of the subjects were classified into these three intermediate categories and by the definition in the ASHRAE 55 standard, this situation indicates neutral conditions. Also, 57.8% of people prefer the temperature to remain unchanged, while the percentage of those who demand unchanged humidity is 69.7%. In the case of airflow, 45% demanded more airflow and 45% preferred no changes in airflow.

Table 1. Logistic Regression of Psychological Components and Adaptive Behaviors

Variable	Degrees of freedom	Omnibus-Chi-square	**Nagelkerke** R Square	Cox and Snell	Hosmer& Lemeshow Test - Chi-square	Overall percentage	Yes%	No%
decrease in temperature	5	6.651^{*}	0.090	0.060	1.932	75.9	4	97.6
	Wald Test (Resilience)= 5.937^{*}			EXP(B) = 1.058				
	Log -odd: $g_{pred} = -6.216 + 0.057(R)$							
	Min (R)= 0.000				Max (R) $=$ 3.08			
*: P Value ≤ 0.05; * *: P Value ≤ 0.01								
Logit equation: $e^{g_{pred}}/(1 + e^{g_{pred}})$								

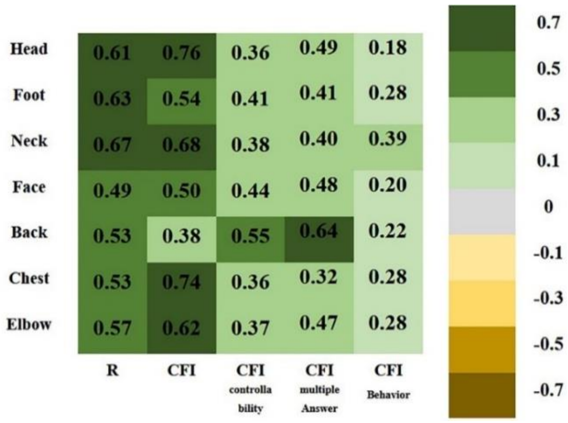

Fig 8. Correlation between Psychological Component and Point Feelings

Table 2. Correlation between Psychological and Environmental Components

Variable	Pearson Correlation Coefficient			
	T_{in}	RH_{in}	T_{out}	RH_{out}
R	-0.06	-0.02	-0.06	0.03
CFI	-0.06	0.13	0.06	-0.07
$CFI_{controllability}$	-0.03	-0.06	-0.10	0.03
$CFI_{multiple\ Answer}$	-0.06	-0.08	-0.05	0.05
$CFI_{Behavior}$	-0.19^{*}	0.24^{*}	0.14	-0.08
*: P Value ≤ 0.05; * *: P Value ≤ 0.01				
Regression Model	$CFI_{Behavior} = -0.376(T_{indoor}) + 16.234$ *Equation 1. Regression model of CFI*		R Square= 0.040	

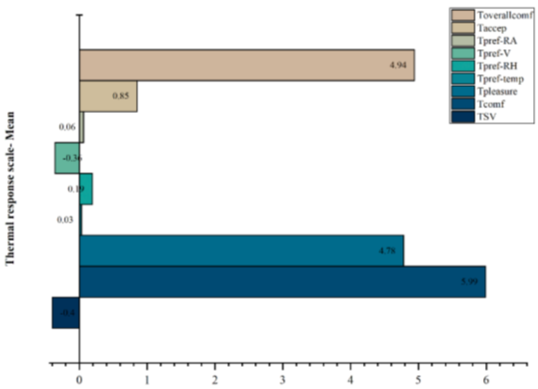

Fig 9. Mean of Different Thermal Responses based on Equation 1 in Table 2

Thermal responses, including TSV, $T_{pleasure}$, T_{comf}, and T_{accept} have shown standard conditions for users; however, looking in the T_{pref}, changes still needed to be made in some cases. Therefore, T_{pref} became a basis for comparing the average score of cognitive flexibility and resilience to determine the status of personal psychological characteristics that needed to be changed or kept the same thermal situation. Participants with neutral TSV had a mean cognitive flexibility of 75.06 and a mean resilience of 85.60 that have been very far from the maximum score. The point is participants with thermal sensation in the three middle groups (neutral, slightly warm, and slightly cool) have almost the same scores indicating their cognitive flexibility and resilience.

Figure 10 shows that people who tolerate lower temperatures under the studied condition have less cognitive flexibility. The mean score of higher cognitive flexibility was recorded for people who demanded lower humidity, less airflow, and less radiation. On the other hand, the average resilience score was higher in people who prefer less temperature, humidity, airflow, and radiation. In fact, people with higher resilience can handle a wider range of environmental conditions.

Correlation coefficients should also be considered in order to be more accurate in describing the relationship between psychological components and thermal responses. In Figure 11, resilience with $T_{pleasure}$ ($r = 0.194$, $P < 0.05$), T_{comf} ($r = 0.297$, $P < 0.01$), $T_{R\text{-}pref}$ ($r=0.191$, $P < 0.05$), and $T_{overallcomf}$ ($r = 0.25$, $P < 0.05$) based on the Spearman coefficient showed a significant but weak correlation with psychological criteria. Cognitive flexibility also had a weak relationship with T_{comf} ($r= 0.292$, $P < 0.05$). As illustrated in Figure 11, the cognitive flexibility subscales have also shown a significant and weak correlation with thermal responses in some cases. Due to the binary structure of the T_{accept}, the Eta correlation coefficient was used that showed a very weak correlation with psychological components.

It should be noted that psychological components can't be the cause of thermal comfort alone. Because the difference in scores is very small and the correlation between psychological components and thermal response is very low that can't help the final decision.

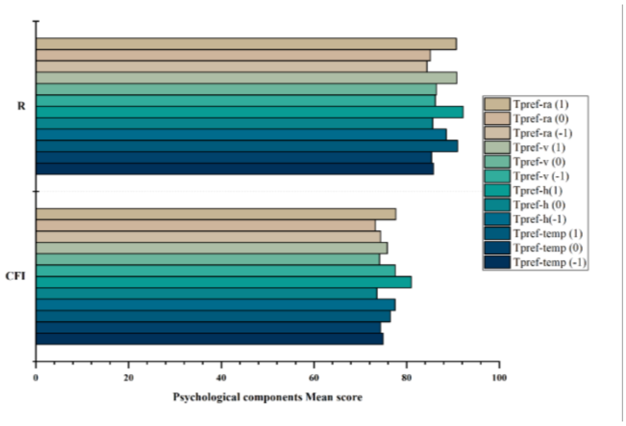

Fig 10. The Mean of Psychological Score in Participants by Different Thermal Preferences

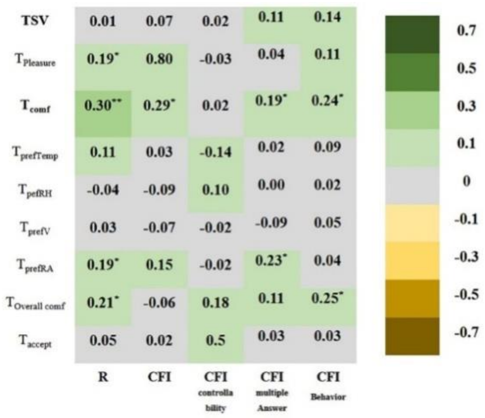

Fig 11. Correlation between Psychological Component and Thermal Responses

4.5. The Cumulative Effects of Personal, Environmental, and Psychological Components on Thermal Responses

In order to measure the collective effect of the studied components, multiple linear regressions was calculated in two modes:

(a) Psychological components (cognitive flexibility and its subscales and resilience) as independent variables and thermal responses (TSV, T_{comf}, $T_{pleasure}$, $T_{pref-temp}$, $T_{pref-RH}$, T_{pref-V}, $T_{pref-RA}$, T_{accept},and $T_{overallcomf}$)as dependent variables.

(b) Psychological, personal, and environmental components as independent variables and thermal responses as dependent variables.

In this case, conscious/unconscious adaptive behaviors in the calculation of the regression were disregarded because of a weak correlation with psychological components. Multiple linear regression models show the thermal response variations based on psychological components and other factors.

In calculating multiple regression models, in the first place, the multicollinearity of the independent variables should be considered. If the variables have a strong correlation with each other, the regression model will not be appropriate. Multicollinearity coefficients were checked with all four coefficients of VIF, tolerance, eigenvalue, and condition index, and if any multicollinearity was considered, the variables changed to their z-standard score. The second point in the multiple regression model is how to enter independent variables that can also yield different results. In practice, there are five methods of data entry including entering, stepwise, removing, forward, and backward. In this study, multiple regressions were investigated by all methods. In a similar way, forward and stepwise methods have shown a better description of the variables' relationships.

Table 3 shows the models that are derived from multiple linear regression for psychological components and thermal responses. As can be seen, there is a significant relationship between TSV, T_{comf}, $T_{pleasure}$, $T_{pref-temp}$, $T_{pref-RA}$, and $T_{overallcomf}$. On the other hand, the influence of the subscales of cognitive flexibility on $T_{pleasure}$, $T_{pref-temp}$, and $T_{pref-RA}$ is greater than the total score of cognitive flexibility on $T_{overallcomf}$. Resilience also affects one's T_{comf} and $T_{pleasure}$.

If we substitute the minimum and maximum scores of each of the affective psychological components in the regression models mentioned in Table 3, the range of variations of each thermal response is determined. Thus, the comfort status of individuals participating in the study sample is determined. Regarding the generalization of results, it should be noted that based on the adjusted R-square, only Model No. 6 provides a wider generalization capability.

Figure 12 shows the thermal response variations based on the effective components mentioned in Table 3. $CFI_{Behavior}$ as a subscale of CFI changes the TSV from slightly warm to slightly cool. However, in any case, the person's thermal sensation is in the neutral temperature state and does not cause much change.

Changes in resilience cause one to move from the level of uncomfortable to a completely comfortable situation on T_{comf} scale. Regarding $T_{pleasure}$, it also leads from slightly unpleasant conditions to slightly pleasant. Thus, the effect of resilience on these two dependent variables is significant. $CFI_{Behavior}$ does not have a significant effect on temperature preference, and in any case, the individual tends to choose an increase in temperature. However, the preference for reducing radiation will increase with the increase in the level of $CFI_{multiple\ answers}$. $T_{overallcomf}$ is also affected by cognitive flexibility and its range varies from tolerable to completely tolerable.

Table 3. Regression Model between Psychological Components and Thermal Responses

Model Number	Adjusted R Square	ANOVA Significance	Regression Model
Model 1.	0.042	0.019*	$TSV = -0.919 + 0.120(CFI_{Behavior})$
Model 2.	0.093	0.001**	$T_{comf} = 2.861 + 0.036(R)$
Model 3.	0.036	0.027*	$T_{pleasure} = 2.589 + 0.025(R)$
Model 4.	0.038	0.047*	$T_{prefTemp} = 0.714 - 0.024(CFI_{Behavior})$
Model 5.	0.050	0.011**	$T_{prefRA} = -1.471 + 0.039(CFI_{DiffrentAnsewrs})$
Model 6.	0.157	0.000**	$T_{overallcomfo} = 1.356 + 0.048(CFI)$

*: P Value ≤ 0.05; * *: P Value ≤ 0.01

Since the personal, environmental, and psychological components were considered simultaneously in this study, their cumulative effect on thermal responses should also be studied. Table 4 shows the models derived from this multiple regression. TSV can only be predicted on the basis of CFI $_{Behavior}$. T_{comf} and $T_{pleasure}$ depend on resilience and body mass index (BMI). $T_{pref\text{-}temp}$ is defined by the indoor relative humidity and the CFI $_{controllability}$ as a subscale of CFI. The preference for humidity does not depend on any of personal or psychological components, but only on the outside air temperature. Preference for airflow is predicted based on outside air temperature and body temperature. BMI as a personal component, indoor air temperature, relative humidity as an environmental component, and CFI $_{multiple\ answers}$ as a psychological component are effective in radiation preference. T_{accept} only depends on the indoor relative humidity. $T_{overallcomf}$ is also justified by the indoor relative humidity and resilience. As shown in Table 4, models 7, 2, 6, 9, and 3 show more generalizability based on adjusted R-square.

In order to find out the status of thermal scales variations based on the models presented in Table 4, each of the effective components has been replaced with their mean values. According to Figure 13, the TSV is neutral when the mean score is entered. Because TSV is only affected by one component, the minimum and maximum effector components can also be calculated. The variations in TSV range from -0.6 to 0.3, which, in any case, is in the neutral temperature range. T_{comf} is in a slightly comfortable condition. Regarding $T_{pleasure}$, the average state is between slightly pleasant to normal situation. $T_{pref\text{-}temp}$ is very close to the option of not having any change. The relative humidity, air flow, and radiation preference with minor amounts lead to the increasing status of each item. Conditions are acceptable on average. $T_{overallcomf}$ is in the situation of slightly tolerable.

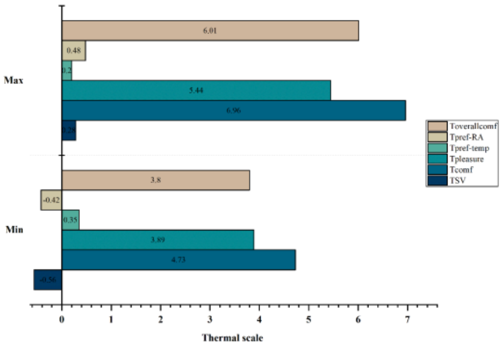

Fig 12. Changes in Thermal Responses based on the Psychological Characteristics of Participants

Table 4. Regression Model between Psychological, Environmental, and Personal Components and Thermal Responses

Number	Adjusted R Square	ANOVA Significance	Regression Model
Model 1.	0.052	0.012*	$TSV = -1.043 + 0.132(CFI_{Behavior})$
Model 2.	0.173	0.000**	$T_{comf} = 5.013 + 0.039(R) - 0.096(BMI)$
Model 3.	0.110	0.001**	$T_{pleasure} = 4.762 + 0.028(R) - 0.096(BMI)$
Model 4.	0.072	0.009**	$T_{prefTemp} = 1.765 - 0.042(RH\ \ ) - 0.026(CFI_{Controllability})$
Model 5.	0.067	0.005**	$T_{prefRH} = 0.687 - 0.061(T_{out})$
Model 6.	0.157	0.000**	$T_{prefV} = -2.880 - 0.121(T_{out}) + 0.117(BodyTemp)$
Model 7.	0.198	0.000**	$T_{prefRA} = -3.523 - 0.061(BMI) - 0.050(RH\ \ ) + 0.044(CFI_{DiffrentAnsewrs}) + 0.193(T\ \ )$
Model 8.	0.085	0.002**	$T_{accept} = 1.877 - 0.025(RH_{out})$
Model 9.	0.121	0.001**	$T_{overallcomfo} = -1.247 + 0.129(RH\ \ ) + 0.036(R)$
Number	Adjusted R Square	Mena	Regression Model
Model 10.	0.368**	23.7 (21-26)	$\text{TcomfortGriffith} = 23.575 - 0.255(BMI) - 0.432\ (RH_{in}) + 0.634\ (T_{indoortemp}) - 0.316\ (RH_{out}) - 0.243\ (CFI_{controllability})$
*: P Value ≤ 0.05; * *: P Value ≤ 0.01			

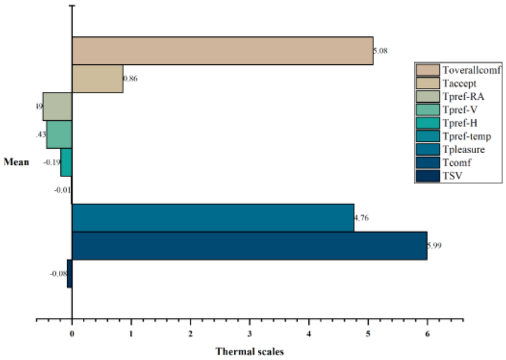

Fig 13. Mean of Thermal Responses based on Regression Models in Table 4

5. DISCUSSION

Determining Thermal Comfort Range and Comparison with Other Studies

To understand satisfaction level in thermal comfort, there is a need to determine thermal comfort temperature and neutral temperature. Two main methods are usually used for the calculation of neutral temperature: a) linear regression between temperature and TSV, and b) Probit analysis in $T_{pref\text{-}temp}$ (Cheung & Jim, 2017). None of these methods could be used in this study for several reasons such as limited range of indoor air temperature, more frequency of TSV in the neutral range, symmetrical distribution of responses in $T_{pref\text{-}temp}$, a small number of samples, and short-term study period. None of the above are considered defects in the study, but it is necessary to choose the appropriate method to calculate the comfort or neutral temperature. According to recent research, since most office buildings are designed with good thermal quality, their indoor temperature standard deviation is almost 0.8 based on ASHRAE and SACTs databases (Aryal & Becerik-gerber, 2018;Damiati et al., 2015; Kontes et al., 2017; F. Nicol & Humphreys, 2007; Takasu et al., 2017). The indoor temperature standard deviation in this study was 0.813 that is very close with other studies. For the validity of results, we check theaccuracy of estimation based on the number of participants and indoor temperature standard deviation with the graph in Hunphreys' recent book (Humphreys et al., 2016). Estimation accuracy of 0.18 was in an acceptable range.Thus, comfort temperature can be calculated based on Griffiths method (Equation 2) that considers thermal sensation change regarding indoor temperature (Aparicio-Ruiz et al., 2019; Rijal et al., 2019). The rate of change or thermal sensitivity (α) can be figured out with ordinal and linear regression (Humphreys et al., 2016). In these two methods, α was assessed to be 0.375 and 0.406. This means a change of 2.2-2.7 in indoor temperature can change participants' thermal comfort. It's very important to know that, in mechanically ventilated buildings, occupants' TSVs change rarely based on this study and other studies (Gunay et al., 2013; Humphreys et al., 2016) but they usually prefer some changes during a day. That's why we suggest always checking $T_{pref\text{-}temp}$ too.

$$T_{\text{comfortGriffith}} = T_{indoor\_temp} + \frac{(T_n - TSV)}{\alpha}$$

Equation 3. The Griffiths Method for Thermal Comfort Temperature

Taking into account the average value of α and placing the values in the Griffiths formula, the comfort temperature range will be 21 to 26°C. Based on the regression model number 10, in Table 4, the cumulative effects of components on $T_{\text{Comfort Griffith}}$ emphasize the role of personal, environmental, and psychological factors. We can call this temperature as "cognitive temperature" that consists of psychological adaptation too. The mean $T_{\text{Comfort Griffith}}$ is the same as the mean indoor temperature that is what we expect in mechanically ventilated buildings. We can also see that $T_{\text{Comfort Griffith}}$ doesn't have any correlation with outdoor temperature and predicated on models with outdoor temperature can lead to thermal dissatisfaction. The role of $CFI_{\text{controllability}}$ in$T_{\text{Comfort Griffith}}$ demonstrates the importance of personal ability to control the surroundings. Running logistic regression models shows the window opening is the only adaptive behavior as a reaction to achieve $T_{\text{Comfort Griffith}}$. This means there wasn't any other possibility for adaptive behaviors.

In most rooms, the thermostat is adjusted to 25℃,while mean $T_{\text{Comfort Griffith}}$ is 23.7℃. The 1.6 difference can cause in 10 to 20% reduction in energy consumption. Temperature higher than 22℃can have a negative effect on cognitive ability (de Dear et al., 2020), so, a lower temperature can improve productivity in office work.

The thermal comfort range in this study was 21-26℃. Although the result cannot be generalized easily, it can emphasize the narrower range of comfort temperature in mechanically ventilated buildings in comparison to natural ventilated ones. As de Dear et al. (2020) highlighted, this happens because of thermal history that people get used to fixing the situation of heating and cooling systems and they usually don't try to change it. The same comfort range can be seen in other studies (Aryal & Becerik-gerber, 2018; Takasu et al., 2017). The mean comfort temperature (MCT) in office buildings in Japan was suggested to be 24℃in winter (Rijal et al., 2017). A field study in Indonesia shows 26.3℃for the MCT (Damiati et al., 2015). In Spain and Brazil, the MCT was 23.6℃,which is 24 for females and 23.2 for males (Maykot et al., 2018). In another study in Brazil, it was 22-26 (Rupp et al., 2018).

In this study, the MCT for males and females are 23.3 and 23.7. This shows females need a little higher temperature. Females are 1.5 times likely to report changes in TSV although other studies show 2.5 times (Karjalainen, 2007). As result, females are more sensitive to temperature, but based on $T_{pref-temp}$, they are more adaptable to the situation as we see in other studies too (Indraganti & Rao, 2010; Maykot et al., 2018). There was noconsiderable difference in conscious adaptive behaviors in males and females in this study although we can say males are more likely to change the environment (Karjalainen, 2007).

6. CONCLUSION

Heat Balance Models emphasize neutral conditionsas an acceptable thermal condition. However, in many field studies, neutral feeling does not match thermal satisfaction. Therefore, HBM and its thermal indices, such as PMV_PPD, can't provide the thermal comfort range accurately. In office buildings where mostly mechanical heating and cooling systems are active, often the temperature is kept at a level that is considered acceptable according to the thermal comfort standards. However, many examples of users' dissatisfaction are always reported. In fact, neutral conditions are not usually the favorite situation in office buildings and the staff may need to change the environment. This is what prompts the need to study the effects of other components on personal thermal comfort. Apart from the environmental and climatic criteria, many other components affect one's thermal comfort. On the other hand, an important part of the adaptation process involves psychological adaptation, which has left a vague point in thermal comfort studies.

Regarding psychological adaptation, the possibility of quantifying the severity and the effectiveness of each component is unclear, and several studies have been conducted in recent years to evaluate these effects while identifying the effective components. Various models have been proposed to illustrate these effects and relationships between variables. The importance of studying the influence of psychological components on the process of thermal adaptation is to help the designer identify the criteria that influence the design. Therefore, in this study, by studying 108 employees in an office building, the effects of personal, environmental, and psychological components on thermal responses were measured. The results of correlation coefficients and different regression models are as follows.

Males, in general, have shown greater resilience and cognitive flexibility. The age group of 46 to 60 years had a higher score in resilience and cognitive flexibility. These two variables have shown strong correlations with each other, such that increased cognitive flexibility increases one's level of resilience. No significant correlation was found between personal components and psychological components (Figure 14). Among the environmental components, only indoor air temperature has a significant relationship with $CFI_{Behavior}$. So, it is possible to predict $CFI_{Behavior}$ based on indoor air temperature by the presented regression model in Table 2.

Among the studied adaptation behaviors, cool drinks and window openings accounted for the highest percentage of selection. Increasing the level of resilience causes the need to lower temperatures. In other words, with increasing personal resilience, she/he would be able to withstand lower temperatures in winter.

Regarding the thermal sensation at a particular point in the body, there was a correlation between this component and the psychological component, but according to the results of logistic regression, it was not possible to estimate the heat/cold sensation at a particular point in the body based on the psychological components.

According to the thermal comfort scales, a high percentage of participants are in comfort conditions according to the ASHRAE 55 standard definition. If the thermal preference that questions the need for change is examined, it is found that people who need less humidity, airflow, and radiation have higher cognitive flexibility and resilience.

Resilience is a component that affects one's thermal comfort and thermal pleasure and its variations can move a person from uncomfortable to comfortable conditions. The ability of the CFI $_{\text{Behavior}}$ influences the radiation needs of the individual. Despite the influence of these components on thermal comfort, thermal pleasure, and thermal preference, the individual's thermal sensation remains unchanged and in the neutral range as defined by ASHRAE 55.

Therefore, the results of the regression models show that the participants perceive a neutral thermal feeling in any case, but require a minimum level of cognitive flexibility to provide overall thermal comfort conditions. Regarding thermal comfort, the resilience score should be a little more than the mean score mentioned in this study. Thermal pleasure and thermal comfort are two measures that have very similar results in this study, so using one of these two scales in the questionnaire is sufficient. Regression models that are declared in Table 4 can help predict the personal thermal response (radiation preference and thermal comfort), based on resilience score, BMI, air temperature, and humidity.

In this study, we tried to investigate some of the ambiguity points regarding users' dissatisfaction with environmental conditions. Therefore, this paper is in line with the results of many studies that have discussed the role of psychological properties in studies related to energy and in particular thermal comfort (D’Oca et al., 2017; Höppe, 2002; Roetzel & Chen, 2016; Schweiker et al., 2017; Shipworth et al., 2016; Von Grabe, 2016).

Although many studies have found that one's psychological adaptation is influenced by one's own habits and experiences, this study found that other individual psychological characteristics may also be affected. At this stage, psychological components such as resilience and cognitive flexibility affect one's perception of thermal comfort.

It is important to consider how to increase the level of these two abilities to help enhance the quality of the indoor environment and in particular thermal comfort. Part of the solutions that are related to human management in an office building is beyond the scope of this article. Another part is the role of the design and operation phase of the building to increase the individual's desire to be in space by providing high quality. Thermal comfort is also a qualitative issue, so as an architect, one can’t rely solely on environmental conditions such as temperature and humidity to provide thermal comfort. In order to find appropriate solutions for cognitive flexibility and resilience, one of the most important issues is the possibility of choosing different options and opening the way for change so that if one is able to modify the environment, he/she can adapt to it.

Specifically, with regard to resilience, awareness of the situation can have a greater impact on acceptance. This awareness, by creating a spatial hierarchy in design, engages individuals in environmental conditions and prepares them for diverse environmental conditions. Continuous measurement and informing the user will also be helpful. The design of flexible spaces to meet the needs of users helps both cognitive flexibility and resilience. Therefore, the collaboration between architects and psychologists is important in improving the quality of the indoor environment.

Although authors tried to consider most related factors and choose the process based on the main goal of the research, other studies can help validate the results. In future research, some points should be considered: checking mean radiation temperature, body temperature in different parts of the body (beside forehead), measuring outdoor temperature simultaneously, and studying other buildings with different characteristics.

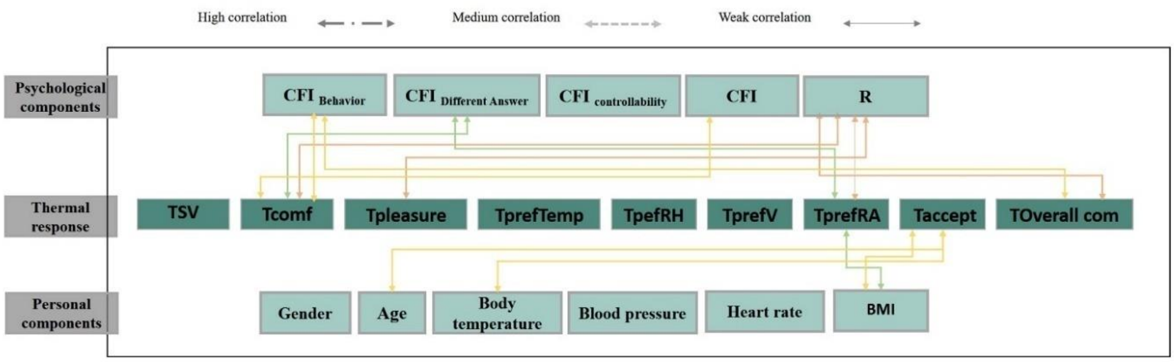

Fig4. The Effects of Personal and Psychological Components on Thermal Responses

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HIGHLIGHTS

- Psychological components such as cognitive ability can affect personal thermal comfort.
- Cognitive flexibility and indoor temperature can predict comfort temperature.
- Comfort temperature is 23.7℃ for this office building based on the Griffiths method.
- At least two degrees change in indoor temperature is needed to shift occupants' thermal sensation.

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